1 QUICK-START

Readers with no understanding of the working principles of the time domain reflectometry (TDR) method of measuring soil water content should read Chapter 7, Principles and Methods for Time Domain Reflectometry, as soon as possible. Briefly, determination of water content with TDR relies on the fact that the travel time of an electromagnetic (EM) pulse through a stainless steel probe (the wave guide), embedded in the soil, is a function of the soil's water content. A schematic of a trifilar TDR probe and the corresponding wave form captured by a TDR cable tester indicates the points of correspondence between the physical parts of the probe (mainly the handle and the ends of the rods) and the inflections of the wave form (Fig. 1-1). The cable tester produces the EM pulse, and records and displays the wave form that results from reflections of the pulse from particular parts of the probe. The horizontal axis of the wave form, although displayed as distance on the cable tester, is actually measured in units of time. Therefore, the wave form can be interpreted manually or by software to find the travel time of the pulse along the exposed length of the probe rods. A calibration equation can be applied to the travel time data to find the water content. In Section 1 of this manual we explain how to set up a TDR system to capture the wave forms from individual probes, either manually or automatically and unattended. The system is controlled by the TACQ software (documented in Chapter 2) which also is capable of interpreting the wave form. The systems we will describe range from the most simple (a cable tester, computer, single TDR probe and software), to complex systems using several multiplexers and hundreds of probes (Fig. 1-2).

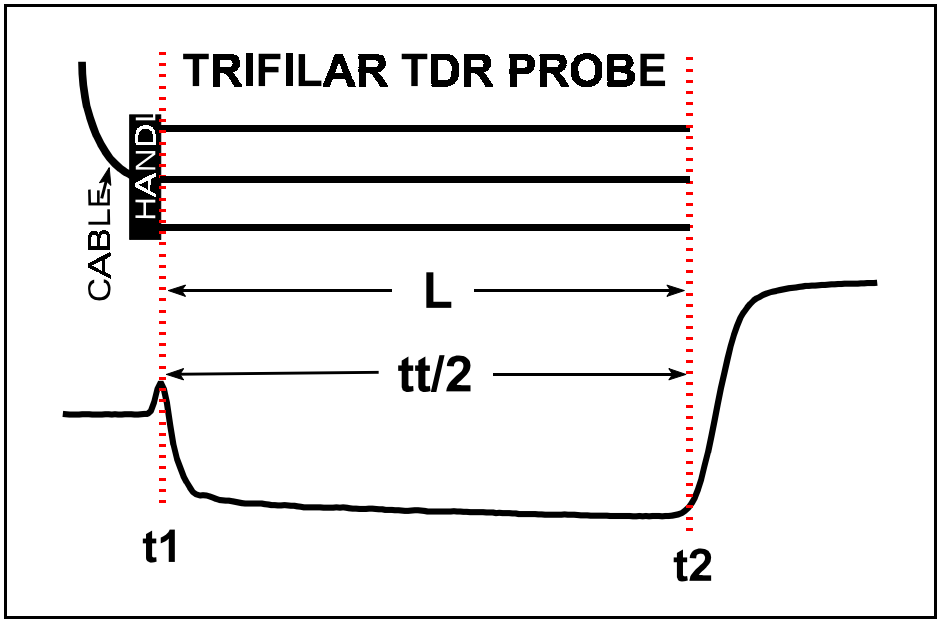

Figure 1-1 Relationship of TDR probe parts (top) to wave form features (bottom) for moist sand. For the wave form the vertical axis has units of voltage and the horizontal axis units of time.

The TDR probes, multiplexer, cables, and software discussed in this text were created by the author, and are now manufactured by Dynamax[1], Inc., Houston, Texas under a Cooperative Research and Development Agreement with USDA.

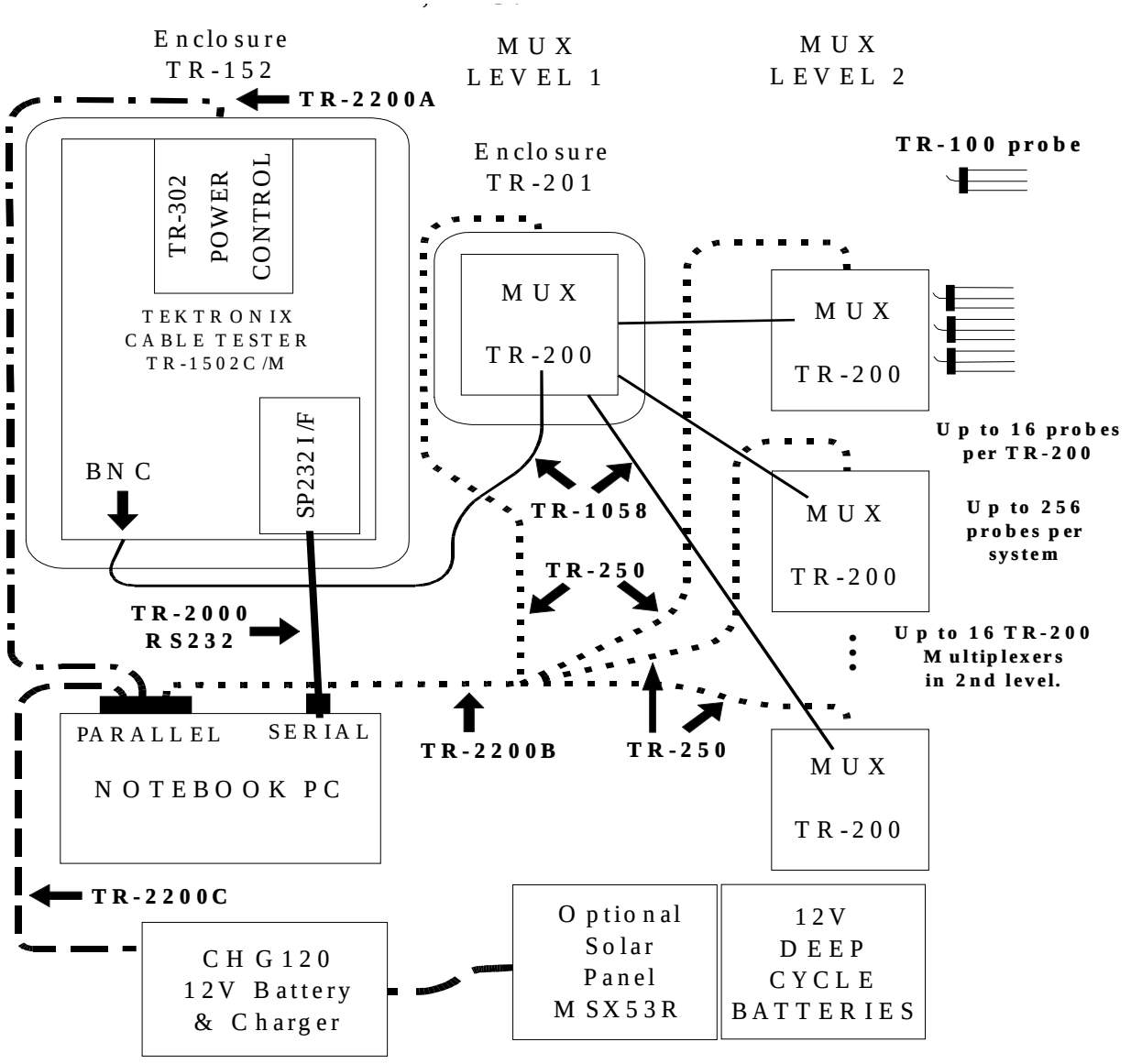

Figure 1-2. Prototypical TDR System Schematic. Model numbers for probes, cables, and the multiplexer are those assigned by the author, and may differ from numbers assigned by Dynamax, Inc.

[1]The mention of trade or manufacturer names is made for information only and does not imply endorsement, recommendation, or exclusion by the USDA-Agricultural Research Service.

1.1 Time Domain Reflectometry (TDR) Systems

The most common minimal system consists of an IBM PC/AT compatible computer running the TACQ program, a Tektronix 1502B or 1502C cable tester equipped with a Tektronix SP232 serial extended function module, a serial cable to connect the two (TR-2001), and a single TDR probe (TR-100) connected to the BNC connector of the cable tester. The computer may be any PC/AT compatible with an RS-232 compatible serial port and Hercules, ATT (640 x 400 monochrome), EGA or VGA graphics. The operating system may be DOS or Windows (see Section 2.2 for special requirements for Windows setup). The serial cable should be a modem type (straight through connections) with a 25 pin D connector (male) for connection to the 1502B/C and either a 9 pin or 25 pin connector (female) as required to connect to the computer. Cable TR-2000 features a 9 pin connector that will plug into the serial port of most recent computers, and a 25 pin connector for the 1502B/C. See Section 3, Cabling, for cable specifications. Note that this system is equivalent to using one computer and cable tester to read many probes which are connected one at a time to the cable tester for data acquisition.

A second minimal system consists of the computer with operating system as specified above, and a TDR probe. But the computer is connected to a Tektronix 1502 cable tester that has been specially modified by Dynamax for serial digital output of the wave form (the 1502 normally outputs the wave form as an analog signal over a 20 s period). The computer and cable tester are connected using a special serial cable that has a 9 pin female connector that plugs into the computer's serial port and a round five pin connector that plugs into the Dynamax modified X-Y Output Module of the 1502.

Sections 1.2 and 1.3 describe setup and first use of these systems. Sections 1.4 and 1.5 describe more complex systems involving the use of multiplexers to read multiple probes (up to 256).

1.2 Tektronix 1502B or 1502C Cable Testers, Reading Single Probes

If not already installed, install the SP232 module into the cable tester following Tektronix's recommendations (turn off power by pushing in the power switch in the lower right corner of the cable tester front panel). Assure adequate power to the cable tester and computer either by charging the batteries or plugging the units into appropriate AC power outlets (see their manuals for instructions). Plug cable TR-2001 into the computer's serial port and into the 25 pin port of the SP232. Turn on power to the computer and cable tester. If the computer was purchased from Dynamax, the TACQ software will be pre-installed in directory C:\Dynamax. If not, then install the software by creating a subdirectory (your choice of name) on any drive with enough space to accommodate the TDR data files that will be created. The amount of space required may vary from a few hundred kilobytes for manual reading of a few probes to many megabytes for automatic unattended data acquisition from a multiplexing system involving many probes. See Section 2.8, File Formats, for more information. Install the software simply by copying the files TACQ.EXE, TACQ_TDR.INI and TACQ.INI to the subdirectory. You may also copy these files directly to the root directory, C:\, if you won't be bothered by the accumulation of data files there.

Run TACQ from the DOS prompt by typing TACQ and pressing the Enter key. The default setup of the program is for serial communication to the 1502B/C and the program will attempt to initialize communications at startup. You will see several messages on the screen as the subprogram FINDBAUD tests the serial ports and attempts to start communicating with the cable tester. If communication is successful then the main menu of TACQ will appear as shown in Fig. 1-3.

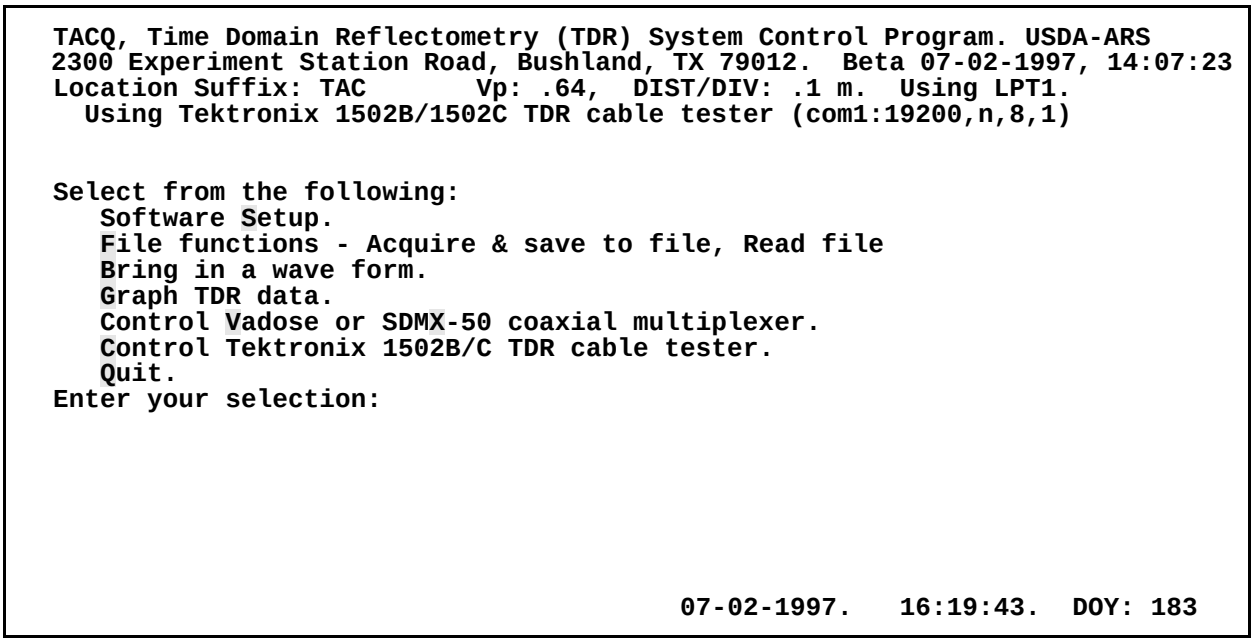

Figure 1-3. Main Menu of program TACQ.

If you see this screen then skip to the next paragraph. If an error occurs in serial communications, a prompt will appear:

```
1502B/C not responding.  Is it turned on?  Is cable connected?
Try again, or quit [Y, N, or Q]:?
```

Check the cable connection and make sure the cable tester is turned on. If the cable tester was off, turn it on and wait 20 s for the cable tester to self-initialize before continuing. If either condition was incorrect then press Y to re-try. If the above prompt re-appears then press N and the Software Setup screen will appear (Fig. 1-4). There are several choices in Setup that may aid serial communications. If the cable tester shown is not correct then press C to change the cable tester, then use the up and down cursor keys to find the Tektronix 1502B/C choice, and press Enter to select it. Press S to change serial communications parameters. If you are using a very long serial cable then enter 1 for the delay for COMM port transmit/receive operations. You might also want to increase the wait for cable tester response from the default of 2. Setting the baud rate to a lower value may also allow serial communications under difficult conditions. If communications have failed, the COMM port will be set to COMM1 by default. Change this to the COMM port that you are using (usually 1 or 2). The program will again attempt to initialize serial communications. If the error persists, quit TACQ and verify that the serial port is working. Many laptop, notebook and subnotebook computers allow adjustment of serial port settings in CMOS setup. Check that the serial port is enabled and what port number it uses (COMM1, COMM2, etc.). Try running TACQ again.

```
                              SOFTWARE SETUP
Cable tester:           Tektronix 1502B/1502C TDR cable tester
Defaults                Vp: 0.64, DIST/DIV: .1 meters
                        Filter: No override.
Serial Port:            COM1:, 19200 baud, Send/Receive delay: 0, Wait: 3
Parallel Port:          LPT1:. Pins for TR-200: DATA 2, CLOCK 3, SDE 4
                               Pins for SDMX50: DATA 6, CLOCK 7, SDE 8
                               Delay between clock ticks is approx. .006 s.
                               Power Control Pin: 9
                               Continuous power to cable tester.
File Names:             Wave forms: 1997183T.TAC.  Water contents:
1997183W.TAC
                        Bulk electrical conductivity: 1997183E.TAC
Acquisition Interval:   1800 s.
Set Time/Date:          07-02-1997,  16:33:15
Multiplexer & Probe Connections:
Probe Cable Length, Vp, DIST/DIV:
Interpretation methods:
Press C, D, S, P, F, A, T, M, L, I or Esc:
```

Figure 1-4. Software setup screen of program TACQ.

1.2.1 Set Up the Probe in Software Setup.

At the Main Menu of TACQ press S to enter Software Setup. Even though there is no multiplexer we will use probe 1 on multiplexer 1 as a virtual, rather than physical, connection. This allows us to specify the distance to the probe and the Vp and DIST/DIV settings that give the correct wave form position and width on the screen; and have these settings saved so we don't have to enter them the next time that we want to acquire data. Press M to set up multiplexer and probe connections.The next screen shows all the multiplexers and the order in which they are connected:

```
Connection Setup
Multiplexer number, type [in brackets], and address.
No.[TYPE] Address
1[1] 1

Enter number corresponding to location in tree (Press <Enter> to exit):
```

Typically for a new installation there will be only one multiplexer shown; and the onscreen code will be 1[1]1 which indicates multiplexer 1, type 1 (Vadose TR-200), and address 1. Press 1 and then Enter to set up this multiplexer. A multiplexer type choice will be shown:

```
Choose 1 Vadose multiplexer, 2 CSI SDMX50 multiplexer
Enter number:
```

Press 1 (since no multiplexer is connected it doesn't matter what is entered here). Next, enter 1 for the multiplexer address and press Enter. The next screen shows the channels of the multiplexer (16 for the TR-200 and 8 for the SDMX50) and the status of connections to that multiplexer.

```
Channels connected to TDR probes are marked with pluses (+), channels
connected to other multiplexers are marked with number of multiplexer.
Working on multiplexer number & type: 1[1].  Navigate with cursor keys.
Connection    Channel    Probe Length (m)  Acquire What?
                1           0.2000              ?
                2           0.2000              ?
                3           0.2000              ?
                4           0.2000              ?
                5           0.2000              ?
                6           0.2000              ?
                7           0.2000              ?
                8           0.2000              ?
                9           0.2000              ?
               10           0.2000              ?
               11           0.2000              ?
               12           0.2000              ?
               13           0.2000              ?
               14           0.2000              ?
               15           0.2000              ?
               16           0.2000              ?

Toggle Probe connection on/off, Make/Break Multiplexer connection, or
<Esc>.
```

Use the cursor keys to move the highlighted area from channel to channel and from column to column. There are three columns where information may be entered. Moving the highlighted area from column to column changes the prompt shown at the bottom of the screen. The left column is for changing connections. When the highlighted area is in the left column you may toggle a probe connection on or off by pressing P. Press P now and you will see a + sign appear for channel one. Moving the highlighted area to the Probe Length column (middle of screen) allows the probe lengths to be set for each probe. Enter a number here that is the exposed length of stainless steel rod. Moving the highlighted area to the right column allows the type of data collection to be set. Note that if N appears in this column for any channel there will be no data collected even if a probe connection is shown in the left column. When you have set up a probe connection for channel 1, entered the probe length, and chosen the data type as desired, press the Esc key. The next screen will show multiplexer connections (see beginning of this paragraph). Press Enter to exit multiplexer connection setup. A message about the number of probes in the system will be displayed. Press any key and the sequential order of probe acquisition will be displayed. In this example there is only one probe, so the order of acquisition cannot be changed. See Section 1.5 for information on changing the order of acquisition when more than one probe exists. Press Esc to return to the Software Setup screen.

1.2.2 Position the Wave Form on the Screen and Save Position

A probe (TR-100) must be connected to the cable tester in order to position the wave form. Connect a probe and put it in the porous medium to be measured. Press L to set the distance to the probe and position the wave form correctly on the screen. Ignore the brief message that states that multiplexer 1 is switching to channel 1. This is simply an indication that the software is recalling the probe length that we just set. The acquired wave form should appear in a screen similar to Fig. 1-5 (wave form shape may differ). Depending on the length of cable between cable tester and probe the wave form displayed may or may not include the section of interest (i.e., the reflections from the probe). For example, in Fig.

1-5 we see reflections from a 1 m long section of cable immediately after the BNC connector on the cable tester; the probe wave form is not shown (see Fig. 1-7 and 1-8 for examples of properly positioned wave forms). The wave form manipulation screen (Fig. 1-5) allows the user to adjust the cable tester in any way that could be accomplished by manual adjustment of knobs and buttons on the cable tester front panel. See Section 2.6; Setting Cable Lengths, Vp, Dist/Div; for more details of these adjustments. Briefly stated, the user may look at portions of the wave form that represent reflections from different distances from the cable tester. The current distances are displayed at the top of the graph. Pressing the F and B keys will move the window forward (longer distances) and backward, respectively, one window width at a time. Pressing H and then F or B, respectively, moves the window one half of its width in the respective direction. The user must adjust the view forwards or backwards until the wave form is properly positioned. An improperly positioned wave form cannot be correctly interpreted for water content determination by the software. Positioning is done by pressing the F, B, and H keys, or pressing E to enter a distance; by using the S key to fine tune the starting point (left hand side of the screen); and by changing the wave form width on the screen by changing the Vp and DIST/DIV settings. The first step is to find the part of the wave form that represents reflections from the TDR probe.

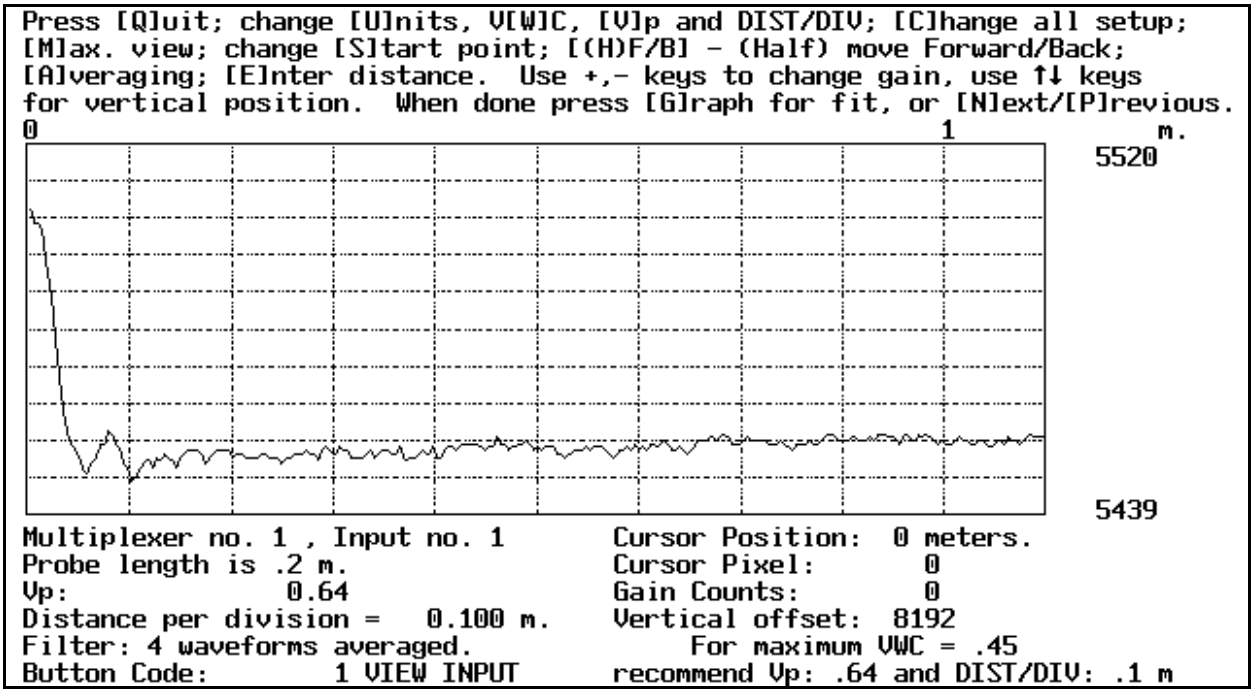

Figure 1-5. Wave form manipulation window before probe wave form is located. The Y-axis of this window automatically scales to display the data full screen. Wave forms will appear more noisy when there is a smaller magnitude between maximum and minimum Y-values.

The window width in length units (DIST/DIV), and the velocity of propagation, Vp, can be changed by pressing V. The Vp is the relative velocity of propagation (relative to the speed of light, c) that the cable tester uses to convert time to distance before displaying the data. Changing either the Vp or DIST/DIV values will change the horizontal width of the wave form shown on the screen. Note that the cable tester actually measures time, not distance, but it displays distance. The displayed distance will be correct only if the Vp setting is appropriate for the cable being used. This is because different cables

use different plastic insulating compounds between the inner conductor and outer conductor (shield) and the different permittivities of these compounds cause the TDR signal to travel faster (lower permittivity) or slower (higher permittivity). For most cables, a Vp setting of 0.66 will cause the distances calculated by the cable tester to be close to the actual distances along the cable. Changing Vp will affect the distances shown on the graph and it will change what is shown in the graph window. Using a smaller Vp will cause the apparent distance calculated by the cable tester to be smaller (distance = velocity x time) and features on the screen will become smaller in width. In effect, the window shows a longer actual view of reflections from the wave guide (this may include views of the wave guide inside the cable tester, in the cable between cable tester and probe, and/or the probe and beyond the probe).

The following procedure will place the wave form fairly close to the desired position. Press V and enter 0.66 followed by the Enter key. Then use the up and down cursor keys to select a DIST/DIV setting equal to the one recommended in the lower right corner of the screen. Measure the length of cable between the cable tester and the probe. Make sure that the units of your measured distance match those on the screen. Press E and enter the distance measured minus about 0.3 m or 1 ft (for Alpha RG58. For Belden RG58 use 0.1 m). The wave form should now include some of the reflections from the probe. Figure 1-6 shows a wave form for a 20 cm probe with a 3 m cable that was positioned using this procedure. Although this is not the desired position, it is close enough to allow fine tuning.

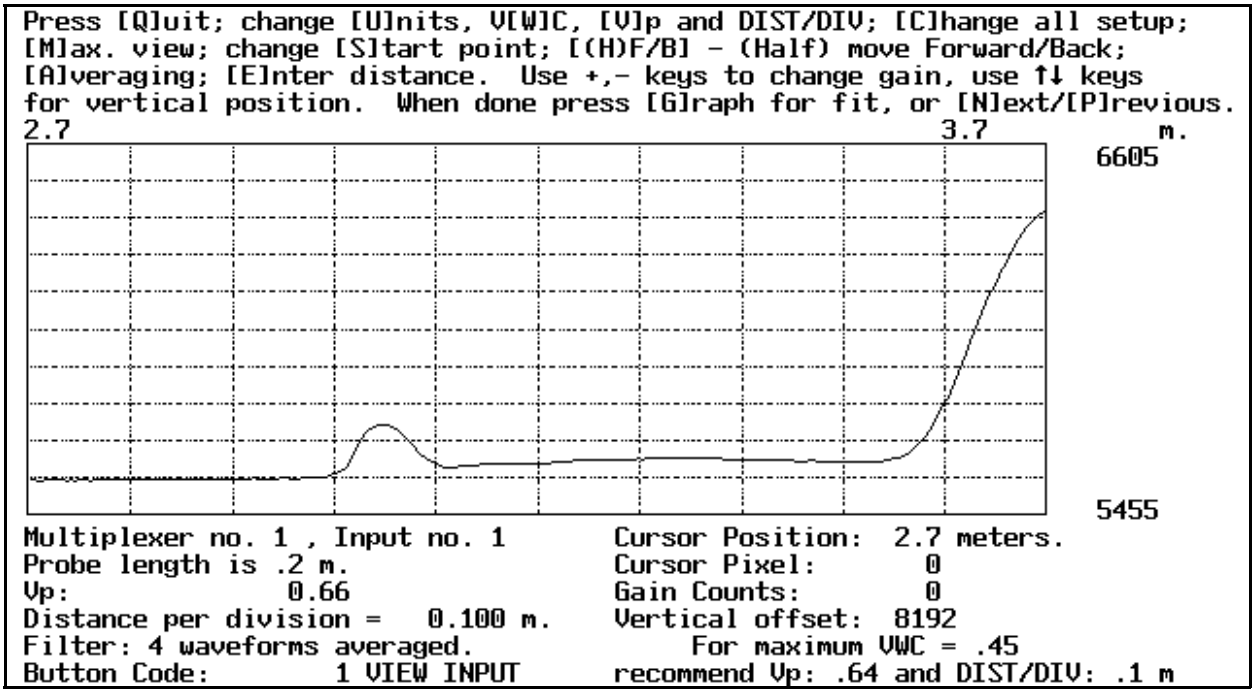

Figure 1-6. Wave form manipulation screen for probe on 3 m cable after first attempt to position wave form. Probe is in saturated sand.

Recommended Vp and DIST/DIV settings for the current probe length are given in the lower right corner of the screen. Enter these to adjust the wave form to the proper width (see Section 2.6 for further discussion of appropriate screen window width). Fine tune the position of the first peak by pressing S and moving the vertical line with the cursor keys. Pressing Esc will re-set the left hand border of the screen to the new position of the line. The desired position of the first peak is just to the right of

the first vertical grid mark (Fig. 1-7).

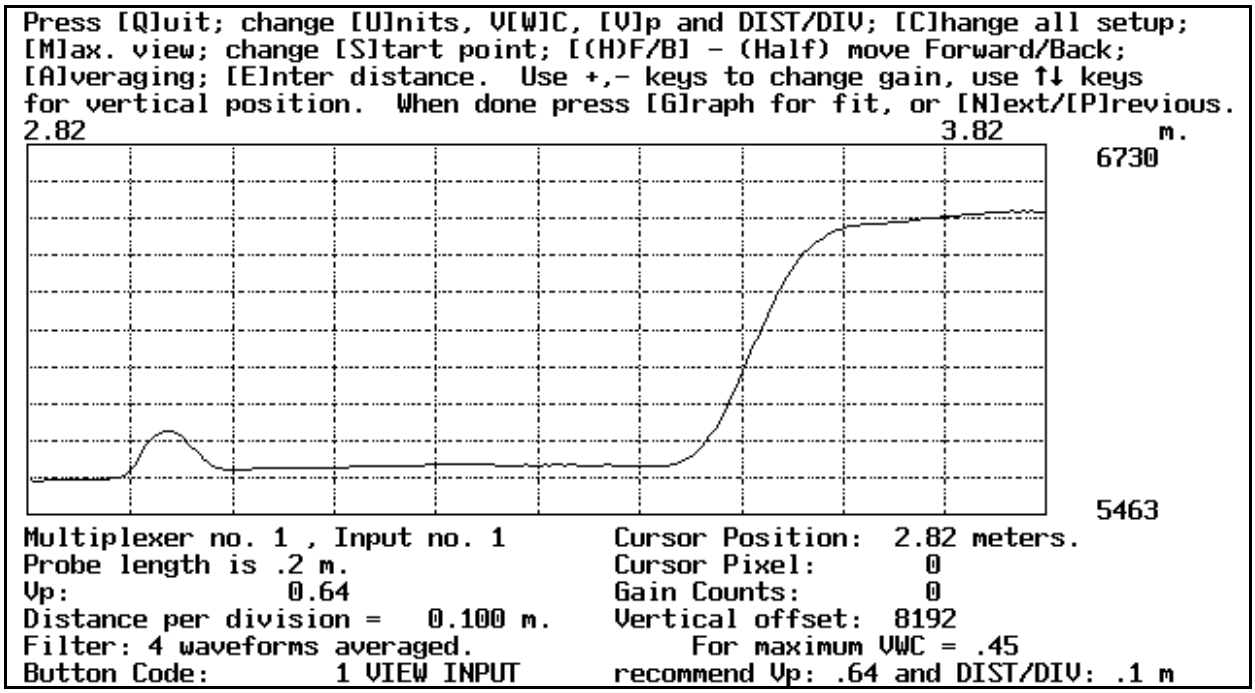

Figure 1-7. Wave form manipulation screen for probe on 3 m cable after adjusting the left hand border by pressing the S key and using the cursor keys. Probe is in saturated sand.

A typical wave form for a probe in dry sand is shown in Fig. 1-8. If the maximum volumetric water content (VWC) shown does not match your expected maximum or saturated water content then press W to change it. Then use the resulting new values of Vp and DIST/DIV. Once the wave form is properly positioned, press G if you want to see how the program will interpret the wave form for water content; or press N for the next probe. Since only one probe was set up in multiplexer and probe connections, this will end the probe position set up and the Software Setup main screen will appear. Press Esc to exit Software Setup, and make sure to save the set up. See Sections 2.4.1.10 and 2.7 for information on changing methods for wave form interpretation (finding of travel times and water contents), and Section 2 in general for information about saving data to files, automatic and unattended data acquisition, and acquisition of data for determination of bulk electrical conductivity. See Section 2.6, for more information on setting the distance to the probe, and setting Vp, and DIST/DIV settings to correctly position the wave form.

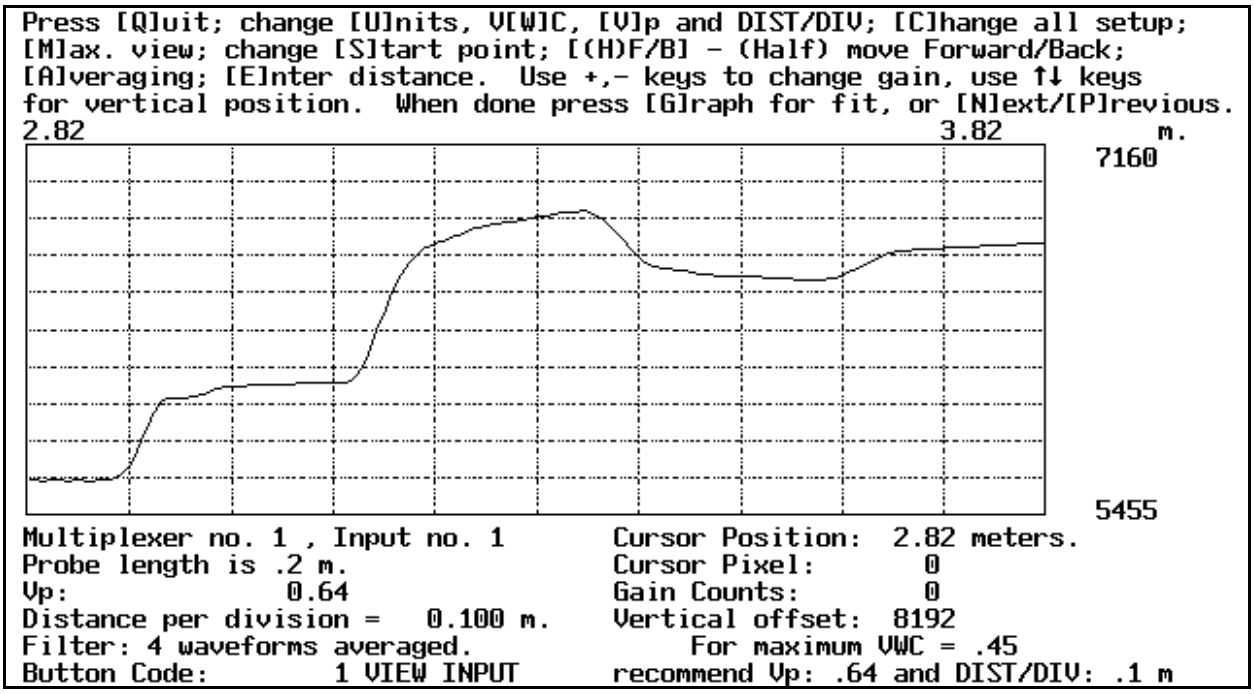

Figure 1-8. Wave form manipulation screen for probe on 3 m cable after adjusting the left hand border by pressing the S key and using the cursor keys. Probe is in air dry sand.

1.2.3 Connect a Probe and Make a Reading

With the probe in the soil (or other porous medium), from the main menu of TACQ (see Fig. 1-3), acquire a wave form and reduce it to water content by pressing F for File functions, and S to acquire a single wave form. Enter a file name or press Enter alone if you don't want to save the data. If a file name was entered, enter a comment when prompted, if desired, otherwise press Enter at the prompt. The comment serves to identify data from different probes if data from more than one probe is saved to the same file. Press Enter when prompted for a multiplexer number and again when prompted for a probe number; this causes the multiplexer number to be set to a default of one, and the probe number on the multiplexer to be set to a default of one. (This example assumes that no multiplexer is connected. Using the default values of one for multiplexer and probe causes the program to recall the probe length, cable length and wave form width information that we set up in Sections 1.2.1 and 1.2.2). Press Enter to accept the default probe length value (exposed length of rods) or enter a value and press Enter to correct the value if necessary. Brief messages will appear on the screen, stating that the multiplexer is switching (ignore this) and that data is being acquired. If the cable length and wave form position were properly set up and saved in Sections 1.2.1 and 1.2.2, then the acquired wave form should appear in a screen similar to Fig. 1-7 or 1-8 (wave form shape may differ).

Press G to graphically interpret the wave form for travel times and water content - the graphical interpretation screen will appear. Press Y to accept the interpretation and the data will be saved to disk. If BEC data were selected during probe connection setup then three additional wave forms will be captured for those data, with brief messages appearing on the screen for each. See Section 2 for more information on file names, formats, and specifying graphical interpretation methods. A prompt will appear asking if another wave form should be acquired. Wave forms from multiple individual probes may be acquired in this manner.

1.3 Dynamax Modified Tektronix 1502 Cable Tester

The Tektronix 1502 cable tester is a completely manually operated device without serial communications capability. When the toggle switch on the front panel is pressed, the 1502 will output a voltage on the Y output pins of the X-Y output module that is proportional to the voltage of the wave form. The output occurs over 20 s during which time a bright dot moves across the cable tester screen. During the 20 s period, the Y output voltage varies according to the height of the wave form at the point on the screen where the moving dot is. Dynamax will modify this cable tester by including a device to digitize the voltage and communicate the digital values to the computer over a serial cable. The modification includes a method of electronically toggling the cable tester to output the wave form voltage. A cable (TR-2002) is needed for connection between the computer (IBM PC/AT compatible with a serial port) and the modified cable tester. With the modification and cable, the TACQ program can toggle wave form output and read in the digitized wave form values through the serial port. See Sections 2.2 to 2.4 for more guidance on software installation, and computer and operating system compatibility. Note that the TACQ program cannot control the 1502 other than toggling wave form output. Adjustments of position of the wave form on the 1502 screen, DIST/DIV settings, relative velocity of propagation (Vp) settings (cable dielectric), gain, etc. can only be made by manual adjustment of the 1502.

Assure adequate power to the cable tester and computer either by charging the batteries or plugging them into appropriate AC lines (see their manuals for instructions). Plug cable TR-2002 into the computer's serial port and into the round 5 pin port of the X-Y Output module in the 1502. Turn on power to the computer and cable tester. If the computer was purchased from Dynamax, the TACQ software will be pre-installed in directory C:\Dynamax. If not, then install the software by creating a subdirectory (your choice of name) on any drive with enough space to accommodate the TDR data files that will be created. The amount of space required may vary from a few hundred kbytes for manual reading of a few probes to many megabytes for automatic unattended data acquisition from a multiplexing system involving many probes. See Section 2.8, File Formats, for more information. Install the software simply by copying the file TACQ.EXE, TACQ_TDR.INI and TACQ.INI to the subdirectory. You may also copy these files directly to C:\ if you won't be bothered by the accumulation of data files in the root directory.

Connect a probe (TR-100) to the cable tester using the BNC connector on the cable tester front panel. Place the probe in the soil (or other porous medium). Adjust the DISTANCE knob on the cable tester until the wave form is on the screen. Adjust the Vp and Distance per Division settings to show the wave form correctly on the screen. For Vp the default, as the modified 1502 is delivered, is 0.99. There are three push-button cable dielectric settings on the front panel. These set the Vp. The 0.99 value is for Air Dielectric - all three buttons should be in the out position. The DIST/DIV value is the product of the values to which the DIST and MULT knobs are set. The MULT knob has two positions: x1 and x.1. Settings that will work with 20 cm probes are Vp of 0.99, DIST of 5 feet, and MULT of x.1 (equivalent to DIST/DIV setting of 0.5 ft).

Run TACQ from the DOS prompt by typing TACQ and pressing the Enter key. The default setup of the program is for serial communication to the 1502B/C and the program will attempt to initialize communications at startup. Since the Dynamax modified 1502 has a different mode of serial communications, an error will occur in serial communications the first time TACQ is run. A prompt will appear:

```
1502B/C not responding.  Is it turned on?  Is cable connected?
Try again, or quit [Y, N, or Q]:?
```

Press N and the following setup screen will appear.

```
                              SOFTWARE SETUP
Cable tester:           Tektronix 1502B/1502C TDR cable tester
Defaults                Vp: 0.64, DIST/DIV: .1 meters
                        Filter: No override.
Serial Port:            COM1:, 19200 baud, Send/Receive delay: 0, Wait: 3
Parallel Port:          LPT1:. Pins for TR-200: DATA 2, CLOCK 3, SDE 4
                               Pins for SDMX50: DATA 6, CLOCK 7, SDE 8
                               Delay between clock ticks is approx. .006 s.
                               Power Control Pin: 9
                               Continuous power to cable tester.
File Names:             Wave forms: 1997183T.TAC.  Water contents:
1997183W.TAC
                        Bulk electrical conductivity: 1997183E.TAC
Acquisition Interval:   1800 s.
Set Time/Date:          07-02-1997,  16:33:15
Multiplexer & Probe Connections:
Probe Cable Length, Vp, DIST/DIV:
Interpretation methods:
Press C, D, S, P, F, A, T, M, L, I or Esc:
```

Figure 1-9. Software setup screen of program TACQ.

Make sure that the correct cable tester (Serial interface to Dynamax modified Tektronix 1502) is chosen. Press C and then the up and down arrow keys to find this choice and then press Enter to choose it.

Press D to change default cable tester values and enter the correct settings for Vp, for DIST/DIV units (feet or meters depending on Tektronix factory setup), and for the Distance per Division. See the cable tester front panel for these settings. The model 1502 cable testers were preset at the factory for units of either feet or meters. Enter the expected maximum or saturated water content, and the probe length when prompted. You will see two possible DIST/DIV choices with corresponding percent errors. The percent error is the difference between the screen width that would be obtained with the current Vp setting and possible DIST/DIV value and the optimum screen width. The error associated with the first DIST/DIV value will be negative or zero, indicating that the screen width would be smaller than optimum. The error for the second value will be positive or zero, indicating that the screen width would be larger than necessary. If the negative value is close to zero then the associated DIST/DIV value may work well. Otherwise, it would be preferrable to use the second DIST/DIVvalue suggested. If neither error is close to zero, you may want to change Vp and see what other combinations may be available. There are three Vp settings that can be set using the pushbuttons on the 1502 front panel: Vp of 0.66 of solid POLY, Vp of 0.70 for solid PTFE, and Vp of 0.99 when all three buttons are out and the VAR screw is turned all the way clockwise. Advanced users may be able to use other Vp values by pushing OTHER and turning the VAR screw. However, this is difficult since the actual Vp setting is not known from the screw position.

Press S to change serial port settings. Enter zero for the transmit/receive delay unless the cable is longer than 2 m, in which case increase this setting until serial communications are stable. Accept the default value of 2 for the wait for cable tester response unless the cable is longer than 2 m in which case you may have to increase the time for stable serial communications. Enter a baud rate of 9600. Enter the number for the serial port to be used (usually 1 or 2). Accept the default settings for parallel

port and pins to be used. Even though a multiplexer is not attached, set up channel 1 of multiplexer 1 with a probe as discussed in Section 1.2.1. This will allow the program to remember the probe length. Exit the Setup screen, saving the setup in the process.

Re-try serial communications. If the error persists, quit TACQ and verify that the serial port is working. Many laptop, notebook and subnotebook computers allow adjustment of serial port settings in CMOS setup. Check that the serial port is enabled and what port number it uses (COMM1, COMM2, etc.). Try running TACQ again. Computers purchased from Dynamax come preconfigured for correct serial port communications.

Acquire the wave form and reduce it to water content by pressing B at the main menu of TACQ. Or, press F, and then S to acquire a water content and save the wave form as well. See Section 2, Documentation for TACQ.EXE, for information on changing methods for wave form interpretation (finding of travel times and water contents), saving data to files, file names and formats, and automatic and unattended data acquisition.

1.4 Systems With One Multiplexer

To connect the computer and cable tester and get the software working, read section 1.2 if you are using the Tektronix 1502B/C cable testers; or Section 1.3 if you are using the Dynamax modified Tektronix 1502.

1.4.1 Connect Multiplexer

The Vadose multiplexer (TR-200) requires 12 VDC power and is controlled by the computer through the parallel port via cable TR-2200B. The TR-2200 cable set features a 25 pin male connector for insertion into the computer's parallel port. Three cables run into this parallel port connector (see section 3, Cabling, for details of pin connections). One cable (TR-2200C) is a two conductor power cable with an automobile lighter adapter for connection to the necessary 12 VDC power supply. Power from this connection is routed through the 25 pin connector housing to the multiplexer - not to the computer. The automobile lighter adapter uses the standard polarity; the center conductor is +12 VDC and the outer shell is ground. A second cable (TR-2200A) is terminated in a three pin, polarized connector that may be plugged into the TR-302 battery power control module for a 1502 or 1502B/C cable tester (see section 6, Solar Power and Power Control, for details on controlling power to the cable tester). The present discussion assumes that power control is not used - it is usually needed only for solar powered systems. The third cable (TR-2200B) is terminated in a 5 pin, polarized connector that plugs into the multiplexer (Fig. 5-1). The multiplexer can be set to one of 16 addresses by moving a jumper on its back side (Fig. 5-2). The multiplexer should be marked with the factory set address. If the marking is no longer present, turn the multiplexer over (remove it from the TR-201 enclosure if necessary) and compare the jumper placement to the address numbers in Fig. 5-2 and note the address (placing a piece of tape on the front of the multiplexer and writing the address there works well). Place the multiplexer on a clean, dry, horizontal surface (or in an enclosure) and connect the cable. Plug the 25 pin connector into the computer’s parallel port.

1.4.2 Set Up Parallel Port

At the main menu of TACQ press S for software setup, then press P for parallel port setup. If more than one parallel port is present, select the one to which the TR-2200 cable is connected. The next three prompts are for setting the parallel port pins used to control the multiplexer. For the TR-2200 cable

these must be set to 2, 3, and 4, in that order (see prompts). The next three prompts deal with parallel port pins used to control the Campbell Scientific, Inc. SDMX50 multiplexer. Press Enter three times to accept the defaults. At the prompt asking for the parallel port pin used to control power to the cable tester, press 9. Then, enter 2 to delay about 0.006 s between clock ticks for parallel port control. Next, enter zero for delay after power is turned on at the cable tester. This will keep the power on permanently if the cable tester is equipped with the TR-302 power control module. If you want the cable tester to be turned off between sets of readings then enter 5 or more seconds for the delay. Enter 5 for the pin used to signal an optional remote controlled AC power strip on and off. Enter zero to keep AC power on always, or enter 1 or more seconds for the delay to have the AC power turned off during data acquisition (sometimes reduces noise on the cable tester). Read Chapter 6, sections 6.6 through 6.9 for more information on options and equipment for power control. Read Chapter 2, section 2.4.1.4 for more information on parallel port settings.

1.4.3 Test Multiplexer and Connect Probes

Turn on the computer and start TACQ. Test the multiplexer as follows. At the main menu of TACQ press V to control the Vadose multiplexer. Press 1 and the Enter key to switch to channel 1; and then enter a number corresponding to the multiplexer address that you just determined, followed by the Enter key. Use a continuity meter or resistance meter (e.g., a digital multimeter) to measure the resistance between the center contact of BNC connector 1 of the multiplexer and the center contact of the BNC connector in the middle of the multiplexer (see Fig 5-1). The resistance shown should be near zero or zero. Next press V, followed by pressing 2 and then press the Enter key twice (you don't have to enter the multiplexer address again because the program remembers it). You should hear a click as the multiplexer relay switches from connector 1 to connector 2. Now, the resistance between the center pin of BNC connector 1 and the center pin of the middle BNC connector should be very high; and the resistance between the center pin of BNC connector 2 and the center pin of the middle BNC connector should be at or near zero. The other 14 channels may also be tested in this manner if desired.

Connect the central BNC connector of the multiplexer to the BNC connector on the cable tester front panel using 50 ohm coaxial cable TR-1058 or equivalent. Proceed to insert the TDR probes in the soil or other porous medium (see Section 4 for advice) and connect the probe coaxial cables to the multiplexer. It is usually best to connect the probes starting with input connector 1 on the multiplexer, then connector 2, etc. If there is a particular order in which you would like the probes to be sensed, connect them in that order. Note that if the older model 1502 cable tester is used (not the 1502B or 1502C models) then all cable lengths to probes must be equal.

1.4.4 Set Up Multiplexer and Probe Connections in Software

At the Software Setup screen, press M to set up multiplexer and probe connections. The next screen shows all the multiplexers and the order in which they are connected:

```
Multiplexer number, type [in brackets], and address.
No.[TYPE] Address
1[1] 1

Enter number corresponding to location in tree (Press <Enter> to exit):
```

Typically for a new installation there will be only one multiplexer shown; and the onscreen code will be 1[1]1 which indicates multiplexer 1, type 1 (Vadose TR-200), and address 1. Press 1 and then Enter to set up this multiplexer. A multiplexer type choice will be shown:

```
Choose 1 Vadose multiplexer, 2 CSI SDMX50 multiplexer
Enter number:
```

Press 1 if it is a TR-200 or 2 if it is an SDMX50. Next, key in the multiplexer address and press Enter. The next screen shows the channels of the multiplexer (16 for the TR-200 and 8 for the SDMX50) and the status of connections to that multiplexer.

```
Channels connected to TDR probes are marked with pluses (+), channels
connected to other multiplexers are marked with number of multiplexer.
Working on multiplexer number & type: 1[1].  Navigate with cursor keys.
Connection    Channel    Probe Length (m)  Acquire What?
              1          0.2000            ?
              2          0.2000            ?
              3          0.2000            ?
              4          0.2000            ?
              5          0.2000            ?
              6          0.2000            ?
              7          0.2000            ?
              8          0.2000            ?
              9          0.2000            ?
             10          0.2000            ?
             11          0.2000            ?
             12          0.2000            ?
             13          0.2000            ?
             14          0.2000            ?
             15          0.2000            ?
             16          0.2000            ?

Toggle Probe connection on/off, Make/Break Multiplexer connection, or
<Esc>.
```

Use the cursor keys to move the highlighted area from channel to channel and from column to column. There are three columns. Moving the highlighted area from column to column changes the prompt shown at the bottom of the screen. The left column is for changing connections. When the highlighted area is in the left column you may toggle a probe connection on or off by pressing P. A probe connection is enabled for a given channel if a + sign appears under Connection on the same row as that channel number. Typically, for a new system setup the column under Connection will be blank. You may also make or break a multiplexer connection to the channel by pressing the M key and following the prompts (see section 1.5, Several Multiplexers for more information). Note that making or breaking probe or multiplexer connections in software does not affect any physical connections. It is the user's responsibility to make sure that the connections indicated in the software setup reflect the physical connections that have been made, or will be, made. You may come back to these setup screens at any time to change probe and multiplexer connections. Moving the highlighted area to the Probe Length column (middle of screen) allows the probe lengths to be set for each probe. The number entered here should reflect the exposed length of stainless steel rod. Moving the highlighted area to the right column allows the type of data collected for each probe to be set. Note that if N appears in this column for any

channel there will be no data collected even if a probe connection is shown in the left column. When all probe connections, probe lengths and data collection choices are set as desired, press the Esc key. The next screen will be the screen showing multiplexer connections (see beginning of this paragraph). Press Enter to exit multiplexer connection setup and a screen detailing the number of probes assigned to the system will be displayed. Press any key and a screen displaying the sequential order of probe data acquisition will be displayed. You may re-arrange the order of acquisition, if desired, by following the prompts. Press Esc to return to the Software Setup main screen.

1.4.5 Set Up Individual Probe Distances and Wave Form Positions in Software

The next step is to set the distance to each probe and to position each probe's wave form correctly on the screen. These settings must be correct in order for the system to correctly find and interpret the wave form for each probe. In order for this part of software setup to proceed correctly, the physical connections that the user has indicated in software must in fact exist and the multiplexer must be properly connected to the computer and cable tester using cables TR-2200, TR-1058; and the TR-250 extension cable if needed. Press L at the Software Setup menu of TACQ. The screen will clear and briefly display a message indicating to which channel on which multiplexer the system is switching. The system automatically switches to the first probe on the first multiplexer. Make the distance, Vp, and Dist/Div setting changes needed for that probe (See Section 1.2.2, Position the Wave Form on the Screen and Save Position, for instructions on how to adjust the wave form to properly show the pulse reflections from the probe). When finished adjusting the wave form, press N to set the wave form for the next probe on the multiplexer; or, press G to see the graph of the present wave form with the tangent lines fitted for travel time and water content determination. Right now it is preferrable to press N rather than G. After all the wave form positions are set up you can go back and look at the fitting. After the user presses N, the system switches to the next probe. The user may press P to return to the previous probe. The user repeats the wave form positioning process for the next wave form. If this is the first time that wave forms have been positioned, the program will use the position data from the previous wave form to position the next one. If all cable lengths are the same then this position will probably be correct and the user can simply press N after confirming that each wave form is correctly positioned. This continues until all connected probes (as chosen by the user in software Connection Setup) are set up for distance, Vp, and Dist/Div.

See Section 1.6 for information on reading all the probes automatically or at any given time, or to read any one probe at one time.

1.5 Systems with Several Multiplexers

The recommended connection scheme (topology) is shown in Fig. 1-2. Connect the second, third, fourth, etc. multiplexers (Mux Level 2) to the first one (Mux level 1) using TR-1058 coaxial extension cables. Plug one end of each cable into the central BNC connector of each multiplexer in Mux Level 2 (see Fig. 5-1). Plug the other end of each cable into one of the 16 BNC connectors on the edges of multiplexer 1. The best practice is to connect multiplexer 2 to channel 1 of multiplexer 1, multiplexer 3 to channel 2 of multiplexer 1, multiplexer 4 to channel 3 of multiplexer 1, etc. This is a tree topology rather than a daisy chain topology. Look at the jumper setting for each multiplexer (see Fig. 5-2) and note the address of each multiplexer. If any multiplexers share addresses, change the jumpers until all multiplexers have unique addresses. If 16 second-level multiplexers are used then two of these may have the same address. But, no second level multiplexer should have the same address as the first level

multiplexer. Use a separate length of TR-250 cable to connect each multiplexer to cable TR-2200(b) at a common connection point. This location should be in a weather tight enclosure, typically the one housing the computer and/or cable tester. At the common connection, wires of the same color should be soldered together; and insulated, either with electrical grade PVC tape or heat shrink tubing. See section 3, Cabling, for cable color codes and pin numbers for connection at the screw clamp connector of each multiplexer. At the other end of each TR-250, wires should be stripped about 6 mm from the end and tinned before clamping in the five pin connector. This connector is then plugged into the multiplexer. To set up the computer and cable tester, read section 1.1 and either section 1.2 or 1.3 as appropriate for the cable tester that is used.

A daisy chain topology is one in which multiplexer 2 is connected to multiplexer 1, multiplexer 3 is connected to multiplexer 2, multiplexer 4 is connected to multiplexer 3, etc. Daisy chaining should be avoided since the TDR signal must pass through many more relays and circuit boards before it reaches some probes as compared with the tree topology for which the signal passes through the same number of relays and circuit boards for all probes.

Note that if the model 1502 cable tester (not the 1502B or 1502C models) is used, then all cable lengths between the cable tester and probes must be equal. This is most easily assured by making sure that all TR-1058 coaxial extension cables, between second level multiplexers and the first level multiplexer, are equal in length; and, that the probe cables are all the same length.

Plug probe cables into the BNC connectors of the multiplexers as desired, usually proceeding from channel 1 to channel 2, etc. (the central connector of each multiplexer is not for probe connection but is for connection to another multiplexer or to the cable tester). For systems with many probes it is helpful to make a sketch showing the connections of multiplexers to each other and probes to multiplexers.

Run the TACQ software and press S to get into the Software Setup menu, then press M for multiplexer and probe connections. The first multiplexer setup screen is shown:

```
Connection Setup
Multiplexer number, type [in brackets], and address.
No.[TYPE] Address
1[1] 1

Enter number corresponding to location in tree (Press <Enter> to exit):
```

Typically, for a new setup, only one multiplexer will be shown, as is shown above. Press 1 and Enter and a multiplexer type choice will be presented:

```
Choose 1 Vadose multiplexer, 2 CSI SDMX50 multiplexer
Enter number:
```

Press 1 to select the Vadose multiplexer and a multiplexer address choice will be presented. Enter the address of multiplexer number 1, i.e. the address of the single multiplexer at MUX level 1. The next screen allows setting of connections for each channel on multiplexer 1. Note that there are no plus signs below 'Connection' in the example above. This indicates that no probes have been assigned to any of the channels. This is typical for a new system setup.

```
Channels connected to TDR probes are marked with pluses (+), channels
connected to other multiplexers are marked with number of multiplexer.
Working on multiplexer number & type: 1[1].  Navigate with cursor keys.
Connection    Channel    Probe Length (m)  Acquire What?
              1          0.2000            ?
              2          0.2000            ?
              3          0.2000            ?
              4          0.2000            ?
              5          0.2000            ?
              6          0.2000            ?
              7          0.2000            ?
              8          0.2000            ?
              9          0.2000            ?
             10          0.2000            ?
             11          0.2000            ?
             12          0.2000            ?
             13          0.2000            ?
             14          0.2000            ?
             15          0.2000            ?
             16          0.2000            ?

Toggle Probe connection on/off, Make/Break Multiplexer connection, or
<Esc>.
```

Also, no numbers appear below 'Connection' indicating that no multiplexer connections have been assigned. Under 'Probe Length' the number 0.2000 appears for all 16 channels. Under 'Acquire What?' there is a question mark for each channel indicating that the desired type of data acquisition has not been set. The position of the highlighted area indicates which property (Connection, Probe Length, or Acquire What?) can be set and for which channel. The default position of the highlighted area is under 'Connection' for channel 1. Use the cursor keys to move the highlighted area across and up and down the screen. Note that the prompt at the bottom of the screen changes to reflect the kind of input that is needed from the user for each column. Under 'Connection' the user can indicate a probe connection or disconnection, respectively, by pressing P to make a plus sign appear or disappear for each channel. Also the user can press M to make or break a multiplexer connection. Under 'Probe Length' the user should change the assigned probe length to reflect the actual length of the probe connected to each channel. Under 'Acquire What?' the user should press W to acquire only water contents (and wave forms), press E to acquire only data (relative wave form levels) for calculation of bulk electrical conductivity, or press B to acquire both kinds of data. Also, the user can press N to acquire no data for a particular probe.

Position the highlighted area under 'Connection' and on the channel to which multiplexer 2 is connected. This is the first multiplexer in MUX level 2 that is connected to multiplexer 1. Typically, multiplexer 2 will be connected to channel 1 of multiplexer 1. Press M and then C to set up the connection in software. Press 1 to indicate a Vadose multiplexer is connected and then enter the address of the multiplexer. The screen below will appear indicating that a multiplexer is connected to multiplexer 1 (in this case to channel 1). Note also that the word Multiplexer appears under 'Acquire What?'. The number 2 under 'Connection' indicates that the connected multiplexer is the second multiplexer or multiplexer 2. The number has nothing to do with the address of multiplexer 2 which may be any address except for the address of multiplexer 1.

```
Channels connected to TDR probes are marked with pluses (+), channels
connected to other multiplexers are marked with number of multiplexer.
Working on multiplexer number & type: 1[1].  Navigate with cursor keys.
Connection    Channel    Probe Length (m)  Acquire What?
    2           1           0.2000          Multiplexer
                2           0.2000               ?
                3           0.2000               ?
                4           0.2000               ?
                5           0.2000               ?
                6           0.2000               ?
                7           0.2000               ?
                8           0.2000               ?
                9           0.2000               ?
               10           0.2000               ?
               11           0.2000               ?
               12           0.2000               ?
               13           0.2000               ?
               14           0.2000               ?
               15           0.2000               ?
               16           0.2000               ?

Toggle Probe connection on/off, Make/Break Multiplexer connection, or
<Esc>.
```

Now move the highlighted area to channel 2 (assuming that this is where the third multiplexer is connected) and repeat the process of making a connection in software resulting in a screen like:

```
Channels connected to TDR probes are marked with pluses (+), channels
connected to other multiplexers are marked with number of multiplexer.
Working on multiplexer number & type: 1[1].  Navigate with cursor keys.
Connection    Channel    Probe Length (m)  Acquire What?
    2           1           0.2000          Multiplexer
    3           2           0.2000          Multiplexer
                3           0.2000               ?
                4           0.2000               ?
                5           0.2000               ?
                6           0.2000               ?
                7           0.2000               ?
                8           0.2000               ?
                9           0.2000               ?
               10           0.2000               ?
               11           0.2000               ?
               12           0.2000               ?
               13           0.2000               ?
               14           0.2000               ?
               15           0.2000               ?
               16           0.2000               ?

Toggle Probe connection on/off, Make/Break Multiplexer connection, or
<Esc>.
```

Repeat this process until all the multiplexers that are physically connected to multiplexer 1 (or that will be physically connected) are shown as connected in software as well. When finished press the Esc key.

```
Connection Setup
Multiplexer number, type [in brackets], and address.
No.[TYPE] Address
1[1] 1
   2[1] 2
   3[1] 3

Enter number corresponding to location in tree (Press <Enter> to exit):
```

Assuming that two multiplexers were connected to multiplexer 1 the next screen will be: This screen also assumes that the addresses of the three multiplexers were 1, 2, and 3 for multiplexer 1 (MUX level 1) and multiplexers 2 and 3 (MUX level 2), respectively.

Now the probe connections to multiplexers 2 and 3 should be set up. Press 2 to see the connection setup screen for multiplexer 2 (below). Move the highlighted area with the cursor keys and press P until a plus sign appears for every channel to which a probe is physically connected. Move to the 'Probe Length' column and enter the actual probe length for each connected probe. Finally, move to the 'Acquire What?' column and make entries indicating the desired type of data acquisition for each probe. The following figure shows the setup for multiplexer 2 when 12 probes, each 20-cm long, have been set up on the first 12 channels. Water content has been chosen as output.

```
Channels connected to TDR probes are marked with pluses (+), channels
connected to other multiplexers are marked with number of multiplexer.
Working on multiplexer number & type: 2[1].  Navigate with cursor keys.
Connection    Channel    Probe Length (m)  Acquire What?
    +             1          0.2000              W
    +             2          0.2000              W
    +             3          0.2000              W
    +             4          0.2000              W
    +             5          0.2000              W
    +             6          0.2000              W
    +             7          0.2000              W
    +             8          0.2000              W
    +             9          0.2000              W
    +            10          0.2000              W
    +            11          0.2000              W
    +            12          0.2000              W
                 13          0.2000              ?
                 14          0.2000              ?
                 15          0.2000              ?
                 16          0.2000              ?

Acquire Water content or Bulk EC or Both or Neither, or <Esc>.
```

Press Esc when through setting up the probe connections for multiplexer 2 and the Connection Setup screen will appear again. Now press 3 to set up the probe connections, lengths and types of data acquisition that reflect the physical connections that have been or will be made to multiplexer 3.

```
Channels connected to TDR probes are marked with pluses (+), channels
connected to other multiplexers are marked with number of multiplexer.
Working on multiplexer number & type: 3[1].  Navigate with cursor keys.
Connection    Channel    Probe Length (m)  Acquire What?
    +            1           0.2000              W
    +            2           0.2000              W
    +            3           0.2000              W
    +            4           0.2000              W
    +            5           0.2000              W
    +            6           0.2000              W
    +            7           0.2000              W
    +            8           0.2000              W
                 9           0.2000              ?
                10           0.2000              ?
                11           0.2000              ?
                12           0.2000              ?
                13           0.2000              ?
                14           0.2000              ?
                15           0.2000              ?
                16           0.2000              ?

Acquire Water content or Bulk EC or Both or Neither, or <Esc>.
```

The figure above shows the screen when 8 probes, each 20-cm long, have been set up for the first 8 channels of multiplexer 3. Repeat this process to set up probe connections for every multiplexer that has been connected to multiplexer 1. In this example, there are 3 multiplexers, and only multiplexers 2 and 3 have probes connected to them.

When finished assigning multiplexers and probes, press Enter at the Connection Setup screen. A screen similar to the following will be displayed. In this example, the previous setup (not shown) had 5 probes assigned to multiplexer 1 and there were no other multiplexers. The current setup has 2 more multiplexers and no probes assigned to multiplexer 1 so there were no probes in common between the old and new setups.

```
There were 5 probes in the system before changes.
There are 20  probes in the new system.
Looking at old probe list...
There were 0 probes common to new and old lists.
Looking at new probe list...
Number of probes in old list: 5
There were 20 new probes.
These will be added to the end of the acquisition list.
Press any key to continue ...
```

Pressing any key will display the following screen which shows the default sequential order of acquisition of data from the probes in the system.

```
Sequential acquisition order:
   1> mux  2, chan.  1          Re-arrange acquisition order of probes:
   2> mux  2, chan.  2          [M]ove one probe at a time;
   3> mux  2, chan.  3          [S]ort by mux #, and channel # on mux;
   4> mux  2, chan.  4          Sort by [R]ecursive search (TACQ default);
   5> mux  2, chan.  5          <Esc> to exit:
   6> mux  2, chan.  6
   7> mux  2, chan.  7
   8> mux  2, chan.  8
   9> mux  2, chan.  9
  10> mux  2, chan. 10
  11> mux  2, chan. 11
  12> mux  2, chan. 12
  13> mux  3, chan.  1
  14> mux  3, chan.  2
  15> mux  3, chan.  3
  16> mux  3, chan.  4
  17> mux  3, chan.  5
  18> mux  3, chan.  6
  19> mux  3, chan.  7
  20> mux  3, chan.  8


Press [M] to move; then use <Pg-Up/Pg-Dn/↑↓>. Press <Enter> to end move.
```

You may follow the prompts and move individual probes to different places in the order of acquisition. Or, you may automatically sort the probes in one of two ways. One sort ranks the probes by multiplexer number and then by channel number on each multiplexer. The other sort is the result of a recursive search of the multiplexer and probe setup. The recursive search order is that used by TACQ prior to the July, 1997 release. If many new probes have been added to ones previously assigned to the system, you may want to press S or R to sort them rather than moving them individually. Press Esc when finished arranging the order of acquisition and the Software Setup menu will appear.

If a Tektronix 1502B or 1502C cable tester is being used, pressing L at the Software Setup menu allows the user to set in software the distance to each probe individually; and to set the Vp and DIST/DIV settings for each probe to the optimal settings for data acquisition given that probe's length. These settings must be made in order for the system to correctly find the wave form for each probe. In order for this part of software setup to proceed correctly, the physical connections that the user has indicated in software must in fact exist and the multiplexers must be properly connected to power and switching signals using cables TR-2200 and TR-250; and to each other and the cable tester using coaxial cables TR-1058. After L is pressed the screen will clear and briefly display a message indicating to which probe on which multiplexer the system is switching. The system automatically switches to the first probe on the first second level multiplexer (multiplexer 2) that is connected to multiplexer 1. The wave form is acquired and graphed on the Wave Form Manipulation Screen. Make the distance, Vp, and Dist/Div setting changes needed for that probe (See Section 1.2.2, Position the Wave Form on the Screen and Save Position, for instructions on how to adjust the wave form to properly show the pulse reflections from the probe). When finished adjusting the wave form, press N to see the wave form for the next probe on mulitplexer 2; or, press G to see the graph of the present wave form with the tangent lines fitted for water content determination. Right now it is preferrable to press N rather than G. After all the wave form positions are set up you can go back and look at the fitting. After the user presses N, the system switches

to the next probe on multiplexer 2. This continues until all connected probes (as chosen by the user in software Connection Setup) are set up. The software then switches to the next multiplexer (multiplexer 3) connected to multiplexer 1 and allows set up for the first probe on that multiplexer, then the second probe, etc. This process continues until all probes that were indicated as connected in Connection Setup have been set up for distance, Vp, and Dist/Div. If you want to go back to a previous probe, simply press P at the Wave Form Manipulation Screen.

1.6 Manual and Automatic Readings

Manual readings from a single probe or multiplexed probes may be made at any time. The instructions given here assume that the system has been properly set up as described in the previous sections. To read a single probe press F at the main menu, followed by S. Enter a file name if you want to store the data to file. If you entered a file name you may also enter a comment at a subsequent prompt. Enter the multiplexer number and then the number of the probe on that multiplexer in succeeding prompts (these will be 1 and 1 if a single probe is connected directly to the cable tester). Accept or change the probe length as desired. When the wave form manipulation screen is displayed, the wave form should be properly positioned - if not then position it here (see Section 1.2.2). Press G to interpret the wave form for water content. After wave form interpretation, press Y to accept the wave form. If a file name was given, data will be saved.

There are three ways to read all probes in a multiplexed system. The first way is to press F at the main menu, followed by A for automatic. When the automatic acquisition screen is displayed you wait for the next acquisition interval as displayed on the screen, or you may read the probes manually by pressing T for test. Note that to use automatic acquisition you should input an acquisition interval in Software Setup. The second way is to press F at the main menu followed by T; which again allows you to read all probes in test mode. The program prompts the user for a file name prefix (up to 8 characters) that will be used to name the output files (see Sections 2.4.3.2 and 2.8 for a description of how the data will be saved). Acquiring data in test mode is slower because the wave form is displayed twice, once for the wave form manipulation screen, and again for the wave form interpretation screen. Also, key presses from the user are required to move from screen to screen, and to accept each wave form. The third way to acquire data from all probes is to type TACQ AUTOSTOP on the DOS command line, followed by pressing Enter (there is a space between TACQ and AUTOSTOP). This will cause TACQ to immediately acquire all the data automatically and without user intervention. The only drawback is that the file names that will be used are the default file names for automatic data acquisition. The user may get around this by first running TACQ and changing the file name suffix in Software Setup; then running TACQ from the command line with TACQ AUTOSTOP; and then re-running TACQ and setting the file name suffix back to its original setting.

Set the acquisition interval in the Software Setup menu before automatic readings are made. Then, at the main menu, press F, then A and wait for automatic acquisition to begin. If no multiplexer is being used (i.e., a single probe connected directly to the cable tester), then make sure that the probe is set up as probe number 1 of multiplexer number 1. In this instance the multiplexer is a virtual device, not physically present in the system; and we are using the setup as probe 1 on multiplexer 1 as a way of recording the probe length, distance to the probe and wave form position so that the system will always find the probe and make a correct reading during automatic acquisition. See Section 1.4 for details of setting up a multiplexer, and see Section 1.2.2 for details of positioning the wave form.